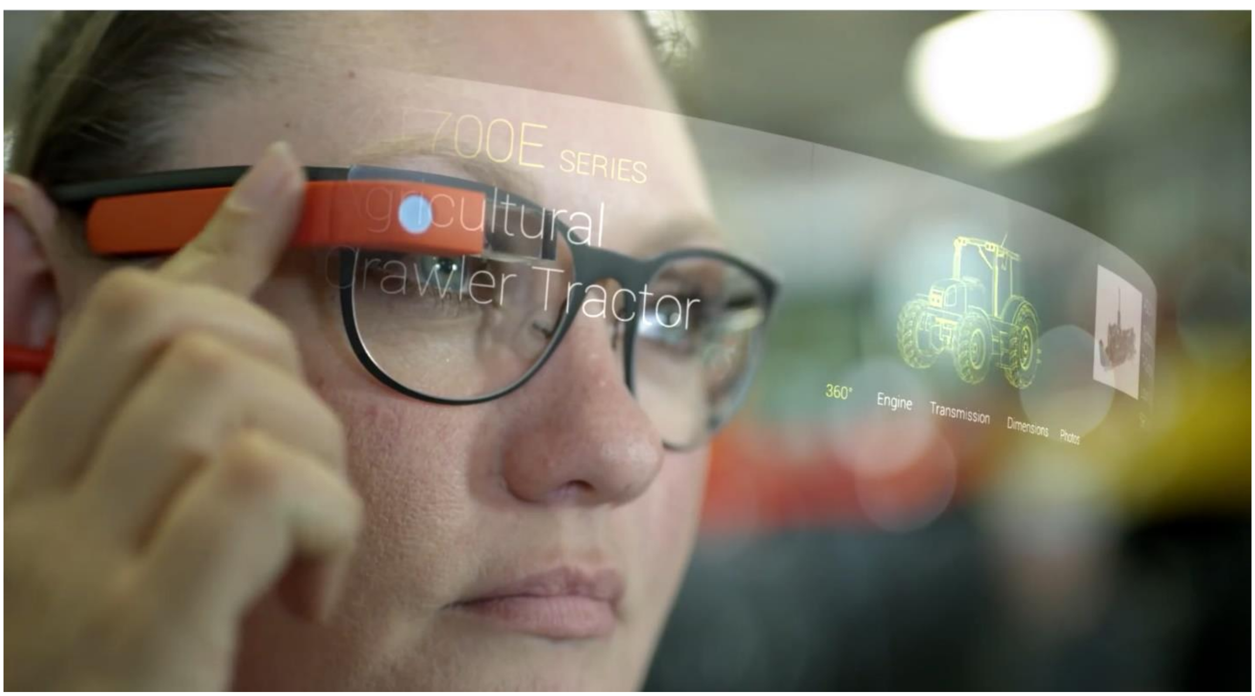
Business White Paper

Smart Glasses on the Shop Floor:

ROI Assessment

based on

OEE Improvement



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Introduction

In today's manufacturing environment, if you're not continuously improving, you're falling behind. Which eventually means becoming uncompetitive and possibly going out of business. Manufacturing companies keep looking for ways to produce *better-faster-cheaper*. Increasingly, improving processes and empowering people depend on better data and smarter technology.

Smart glasses, and the "augmented reality" solutions they support, offer a wide range of benefits, both hard and soft, that accrue over time. Of course, implementing any new technology requires a significant investment in money and resources. That's why it is critical to be able to show a clear, reliable, and significant return on investment.

Unfortunately, calculating ROI is not always easy. Estimating the costs involved is often reasonably straightforward, but many people struggle to quantify and monetize the expected *benefits* of an investment in technology. In manufacturing, the key metric to improve on -and drive ROI- is OEE. The question is: How does technology, such as smart glasses, impact OEE - and how does that translate into ROI? Hopefully, this paper may offer some useful insights.

The Key Metric: Overall Equipment Effectiveness

Improving productivity, by eliminating waste, is a key objective in any manufacturing company, and especially in companies that operate according to lean manufacturing principles. Of course, improving requires measuring. **Overall Equipment Effectiveness (OEE)** is a universally accepted metric for measuring the productivity -and estimating the improvement potential- of a machine, cell, line, or even a whole plant, with one simple number.

As most people in manufacturing know, Overall Equipment Effectiveness (OEE) is defined as the product of **Availability x Performance x Quality**. It shows how efficiently companies are using the available capacity and provides direction on improvement potential.

OEE is pretty easy to understand, and a lot of articles have been written about this topic over the years. In essence, OEE compares the "fully productive time" to the "planned production time". The planned production time is the total scheduled operating time minus any planned downtime, such as breaks, lunches, scheduled maintenance, idle time (when there is nothing to produce), and planned setup or changeover time. The fully productive time is the actual time that was used for good-quality output, after deduction of all the downtime, speed and quality losses.

The figure 1 below provides a visual representation of OEE and its component parts.

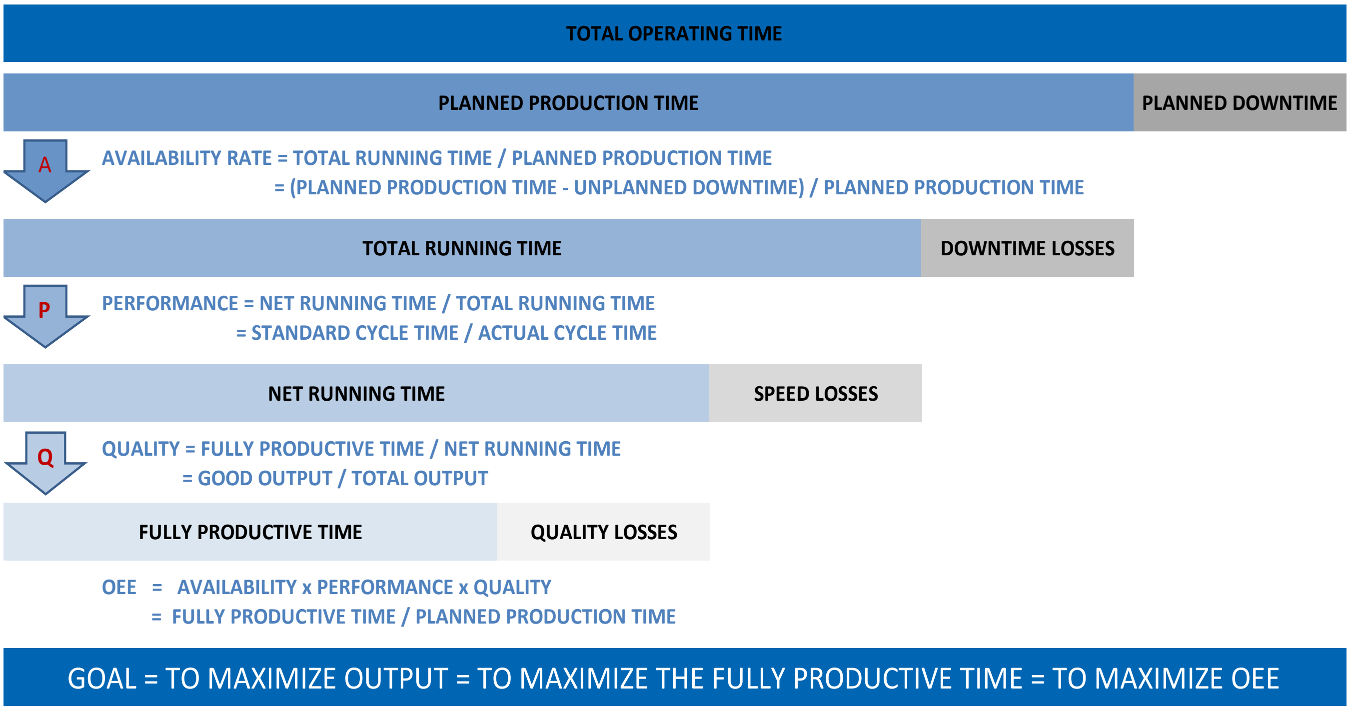

Figure 1: Visual representation of OEE

The **availability rate** represents any **downtime losses**. It takes into account any unplanned downtime that gets recorded, e.g.: equipment failures and breakdowns, process adjustments, material or people shortages, and unplanned setup or changeover time. The availability rate is calculated by dividing the total running time (= planned production time - unplanned downtime) by the planned production time.

The **performance rate** represents any **speed losses**. It takes into account any unrecorded (typically brief) stoppages, misfeeds, reduced speed e.g. due to machine wear or suboptimal machine settings, bad materials, or operator inefficiencies. Any time spent on (“in-line”) rework negatively affects performance rate as well. The performance rate is calculated by dividing the standard cycle time by the actual cycle time.

The **quality rate** represents any **quality losses**. It takes into account both setup and process scrap. The quality rate is calculated by dividing the quantity of good output by the total output produced.

The power of the OEE metric is in its simplicity and in how effective it is in making losses and improvement potential more transparent. Tracking OEE can serve as a catalyst for change.

Improving OEE with Smart Glasses

Using smart glasses with simple but powerful augmented reality solutions to e.g. support digital work instructions and inspections, companies have managed to very significantly improve their availability, performance, and quality rates, resulting in dramatically increased OEE.

Improving Availability

Smart glasses can improve the availability rate by up to 10%.

Effective preventive maintenance has long proven to reduce equipment failure rates, as reflected in metrics such as MTBF ("mean time between failures"). Maintenance technicians, following step-by-step instructions, directly within their line of sight, are able to improve both the speed and quality of their maintenance and repair tasks. They can be alerted automatically when a downtime event happens, or even when an anomaly, such as an abnormal temperature or vibration profile, gets first detected. Operators can perform set-ups and changeovers faster and with less mistakes, reducing the amount of process adjustments needed. These are just a few examples of how smart glasses can help minimize downtime and increase availability.

Improving Performance

Smart glasses can improve the performance rate by up to 40%.

Smart glasses can show critical information when and where that information is most helpful, in an easy to understand format. Complex work instructions can be presented in simple and easy to follow steps. Operators, maintenance technicians, and quality inspectors have access to relevant pictures, schematics, diagrams, tables, checklists, images and videos - right in their line of sight, and even voice-controlled. They can record all kinds of information (values, textual reports, audio, photo, video) while doing the work, and send follow-up action items to support functions when needed.

The availability and accessibility of vital information supports greater overall productivity, enabling workers to do their jobs with first-time-right quality, and resolve any issues quickly and efficiently, all while keeping their hands free. Simply reducing the amount of rework can already have a very positive impact on the performance rate. Making sure machines are set up properly and according to the correct process parameter settings is critical as well for optimal quality and performance (i.e. production speed). All of which can be supported by augmented reality solutions on smart glasses.

Improving Quality

Smart glasses can improve the quality rate by up to 50%.

Lack of compliance with standardized work can lead to increased quality defects, cause significant complaints, returns, and claims, and possibly even have catastrophic consequences. Better than any other tool currently available, digital work instructions on smart glasses support standardized work, significantly improving first-time-right setups and first-time-right production activities, resulting in dramatically reduced scrap and rework.

Smart glasses also improve the speed and quality of inspections, significantly increasing the efficiency and reliability of quality control / quality assurance operations.

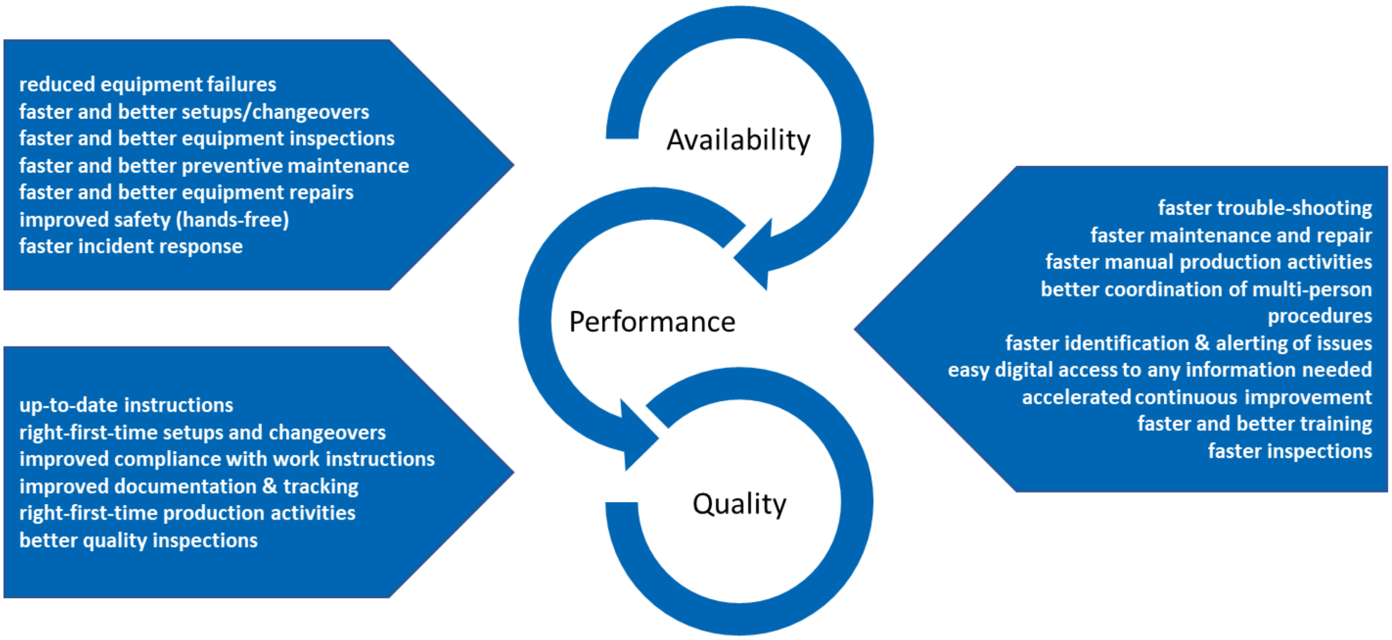

Figure 2: Some OEE improvement use cases

Using smart glasses, early adopter companies have achieved very significant improvements in quality, availability, and performance - and therefore OEE.

But how can this improvement potential be estimated *ahead of time*, and how do OEE increases translate into real bottom line impact?

Estimating OEE Improvement

OEE improvement potential can be calculated in a lot of detail. However, rather than confusing precision with accuracy, it is often sufficient to estimate at a higher level as explained below.

Quality rate and availability rate can never be increased above 100%. So, for quality and availability, the most practical way to define improvement is: “What % of the current losses can be prevented by deploying the new technology?”

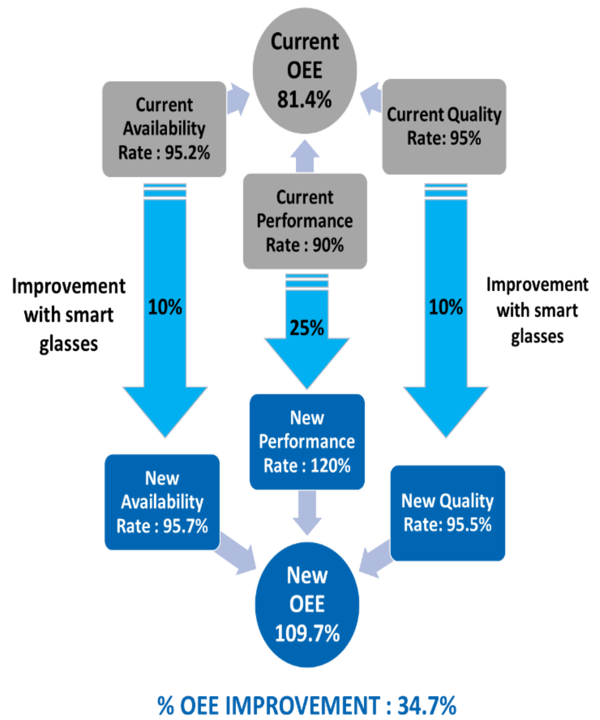

Figure 3: OEE improvement calculation example

A quality rate of 95% means total quality losses of 5%. A 10% reduction in quality losses would result in an improved quality rate of 95.5%, as shown in the figure 3. Similarly, reducing unplanned downtime with 10% would improve the availability rate from 95.2% to 95.7%, as shown in the example.

The performance rate, on the other hand, *can* be improved above 100% of current standard. Especially for manual activities, such as assembly, fabrication, quality inspections, maintenance and repair activities, etc. – which are some of the typical use cases for smart glasses in manufacturing.

The easiest way to assess improvement potential of the performance rate is to focus on reducing the associated cycle time. For example: assuming a current actual cycle time of 20 minutes, a 25% improvement in performance will reduce the average cycle time from 20 to 15 minutes. This is a very significant, and often very achievable improvement in speed, when cutting out all the typical waste of operating without quick and easy access to all the necessary information.

Assuming the standard cycle time is 18 minutes, that means the current performance rate is 18/20 = 90%. Reducing the cycle time from 20 to 15 minutes means the new performance rate is 18/15 = 120% - or a performance rate improvement of (120-90)/90 = 33%.

Taking everything together, the new OEE will be 95.7% x 120% x 95.5% = 109.7%, representing an increase in productive capacity of (109.7-81.4)/81.4 = 34.7%! (Obviously, the standard cycle times will eventually be adjusted down to catch up with and reflect the improved performance, which will push the OEE metric -‘on paper’- below 100% again.)

Now, how can these efficiency and capacity gains be monetized?

Impact of OEE Improvement on Operating Profit

Company XYZ Inc. is considering a proof-of-concept pilot project to implement digital work instructions using smart glasses on their ABC production line.

XYZ Inc.'s approximated cost structure for production line ABC is shown in the figure 4 below:

annual sales revenue within the scope of the project:	**100%**	**$4,800,000**
raw materials cost as % of revenue:	**50%**	$2,400,000
direct labor cost as % of revenue:	**10%**	$480,000
manufacturing overhead cost as % of revenue:	**10%**	$480,000
cost of goods sold:	**70%**	**$3,360,000**
gross profit:	**30%**	**$1,440,000**
SG&A expenses as % of revenue:	10%	$480,000
operating income:	**20%**	**$960,000**

Figure 4: cost structure of company XYZ Inc.

Some of the main scenarios to be evaluated:

- whether XYZ Inc. can benefit from less-than-full-time labor savings, or not
- whether production line ABC is capacity constrained, and therefore not able to keep up with existing market demand, or not
- whether XYZ Inc. is able to increase total sales revenue and operating profit by reducing the average sales price for the products made on their ABC production line

Less-than-full-time labor savings (or not)

The figure 5 below shows what happens when production line ABC is not capacity constrained and unable to increase sales volume, and assumes XYZ Inc. can benefit from less-than-full-time labor savings:

	Current	% Change	Future
annual sales revenue for the product line:	**$4,800,000**	**0.0%**	**$4,800,000**
raw materials cost:	$2,400,000	0.0%	$2,400,000
direct labor cost:	$480,000	-34.7%	$313,415
manufacturing overhead cost:	$480,000	0.0%	$480,000
cost of goods sold:	**$3,360,000**	**-5.0%**	**$3,193,415**
gross profit:	**$1,440,000**	**11.6%**	**$1,606,585**
SG&A expenses:	$480,000	0.0%	$480,000
operating profit:	**$960,000**	**17.4%**	**$1,126,585**

Figure 5: OP gains when not capacity constrained and including less-than-full-time labor savings

All else remaining equal, XYZ Inc. is saving 34.7% on direct labor cost, thanks to the productivity improvements reflected in their OEE performance. Which results in 17.4% or $166,585 extra operating profit.

The figure 6 below shows what happens when XYZ Inc. *cannot* reassign people part-time to other production lines or other duties:

	Current	% Change	Future
annual sales revenue for the product line:	**$4,800,000**	**0.0%**	**$4,800,000**
raw materials cost:	$2,400,000	0.0%	$2,400,000
direct labor cost:	$480,000	-25.0%	$360,000
manufacturing overhead cost:	$480,000	0.0%	$480,000
cost of goods sold:	**$3,360,000**	**-3.6%**	**$3,240,000**
gross profit:	**$1,440,000**	**8.3%**	**$1,560,000**
SG&A expenses:	$480,000	0.0%	$480,000
operating profit:	**$960,000**	**12.5%**	**$1,080,000**

Figure 6: OP gains when not capacity constrained and excluding less-than-full-time labor savings

In case XYZ Inc. is unable to benefit from less-than-full-time labor savings, it can still reduce its direct labor cost with 25%, instead of the full 34.7% productivity increase, resulting in an operating profit increase of 12.5% or $120,000 annually!

Production line is capacity constrained (or not)

But, what if production line ABC is capacity constrained, i.e. if there is more market demand than what XYZ Inc. can currently fill?

The figure 7 below shows what happens if XYZ Inc. is able to turn the full 34.7% extra capacity -created by implementing an effective augmented reality solution- into 34.7% extra sales.

Obviously, the increase in sales volume will require a proportionate increase in raw materials cost. But, as the extra sales volume is made possible thanks to direct labor productivity improvements, this should not increase the direct labor cost. (Including or excluding less-than-full-time labor savings does not make a difference in this extreme example of selling every bit of the extra capacity made available.) Moreover, by using the existing machinery more efficiently, there will not be any significant increase in manufacturing overhead cost either. And, assuming XYZ Inc. does not incur any significant extra sales, general, and administrative (SG&A) expenses to support the sales increase, it will find itself in the very fortunate situation as show below:

	Current	% Change	Future
annual sales revenue for the product line:	**$4,800,000**	**34.7%**	**$6,465,853**
raw materials cost:	$2,400,000	34.7%	$3,232,926
direct labor cost:	$480,000	0.0%	$480,000
manufacturing overhead cost:	$480,000	0.0%	$480,000
cost of goods sold:	**$3,360,000**	**24.8%**	**$4,192,926**
gross profit:	**$1,440,000**	**57.8%**	**$2,272,926**
SG&A expenses:	$480,000	0.0%	$480,000
operating profit:	**$960,000**	**86.8%**	**$1,792,926**

Figure 7: OP gains when capacity constrained and being able to fill the full capacity gained

Being able to sell the full 34.7% extra capacity, which was made available through the productivity improvements achieved thanks to the implementation of digital work instructions on smart glasses, results in an increase in operating profit of 86.8% or $832,926 extra per year!

That is a best-case scenario, of course. But it clearly illustrates the kind of leverage or “multiplier” effect productivity improvements can have. And there are a lot of in-between scenarios that are still very beneficial to XYZ Inc.

The figure 8 below shows what happens when XYZ Inc. can sell just 10% more thanks to the increase in capacity: an increase in operating profit with 37.4% or $358,585 annually!

	Current	% Change	Future
annual sales revenue for the product line:	**$4,800,000**	**10.0%**	**$5,280,000**
raw materials cost:	$2,400,000	10.0%	$2,640,000
direct labor cost:	$480,000	-24.7%	$361,415
manufacturing overhead cost:	$480,000	0.0%	$480,000
cost of goods sold:	**$3,360,000**	**3.6%**	**$3,481,415**
gross profit:	**$1,440,000**	**24.9%**	**$1,798,585**
SG&A expenses:	$480,000	0.0%	$480,000
operating profit:	**$960,000**	**37.4%**	**$1,318,585**

Figure 8: OP gains when turning just 10% of the 34.7% total capacity gain into extra sales

Sales increase through price reduction

In order to boost sales revenue, XYZ Inc. could decide to lower its average pricing a bit for the products manufactured on line ABC.

The figure 9 below shows how XYZ Inc. makes 27.4% or $262,585 in extra operating profit thanks to boosting sales revenue by 20% based on an average price reduction of 5%:

	Current	% Change	Future
annual sales revenue for the product line:	**$4,800,000**	**14.0%**	**$5,472,000**
raw materials cost:	$2,400,000	20.0%	$2,880,000
direct labor cost:	$480,000	-14.7%	$409,415
manufacturing overhead cost:	$480,000	0.0%	$480,000
cost of goods sold:	**$3,360,000**	**12.2%**	**$3,769,415**
gross profit:	**$1,440,000**	**18.2%**	**$1,702,585**
SG&A expenses:	$480,000	0.0%	$480,000
operating profit:	**$960,000**	**27.4%**	**$1,222,585**

Figure 9: OP gains when lowering average price with 5% and selling 20% more volume

The different cases covered so far illustrate the kinds of benefits made possible by the break-through technology of digital work instructions on smart glasses. But what about costs and return on investment?

Calculating Return on Investment

There are a number of different ways to make investment decisions, including net present value, internal rate of return, and payback period. But the simplest approach is to calculate return on investment as follows:

$$\text{ROI} = \frac{\text{Total Cumulated Profits}}{\text{Total Cumulated Costs}}$$

Total cumulated costs

The total cost of implementing digital work instructions on smart glasses will depend on the company specific situation, of course. An overview of the main cost factors involved is shown in the table below:

Software	Typically, companies pay either a perpetual license, in case of on-premise installation, or a monthly or annual subscription fee, in case of software as a service (SaaS). Different software companies use different pricing models, but the cost per operator can be as low as $50/month - or even less.
Hardware	Assuming the existence of a decent wireless network, the only hardware needed is the actual smart glasses. There are many different types of smart glasses nowadays, and they differ in price a good bit. Gemba Systems typically implements "assisted reality" (or "informed reality") solutions, using devices such as Google Glass, Iristick.Z1, Vuzix M300, and RealWear HMT-1. The cost, including frames and shields, ranges between $1,500 and $2,500 per device.
Installation & Configuration	The installation and configuration cost is typically very limited - especially when using software as a service. The IT department may need to configure a dedicated server to run the software on, in case of an on-premise installation, and set up a (separate) wireless network.
Integration	A lot of extra benefits can be gained when integrating smart glasses with enterprise and manufacturing execution systems such as ERP, MES, CMMS, PLM, WMS and LIMS. But existing work instructions are typically not integrated with anything yet - as they are most often created in word processing, presentation, or spreadsheet software... and then printed on paper! So, there is typically no need to take on a bunch of integration work too soon when implementing digital work instructions on smart glasses. Some cases, such as picking or real augmented reality applications, do require integration upfront. In which case the cost depends on systems involved and level of integration required.
Training	Operators will need to be trained on using the smart glasses. With user friendly software and easy-to-use smart glasses, operators can typically be trained in about 20 minutes. After which it just takes a couple of days at most to become fully accustomed to the new technology. Someone also has to create and maintain the digital work instructions for the operators. This "administrator" will need to get trained on the smart glasses' authoring platform. But even an administrator can be fully trained in about 2 days.
Content creation or adaptation	The amount of effort and cost required for content creation or adaptation will depend on the company's specific situation: • How many procedures need to be put on the smart glasses? • How long and how complicated are the procedures? • How similar are the procedures? • What is the quality of the existing procedures? • Are all the required materials available in digital form? • Are the existing procedures residing in a structured, digital platform already, which could be integrated with the smart glasses platform?

Figure 10: Smart Glasses implementation costs

All in all, the total implementation cost for digital work instructions and inspections on smart glasses tends to lay anywhere between $50,000 and $250,000 per plant, including the time and cost of internal resources. A typical proof-of-concept takes 2 to 3 months. A full implementation typically takes between 6 and 12 months. After that, the main cost recurring is content creation and adaptation to keep all active work instructions up-to-date, and to add further work instructions to the platform.

At XYZ Inc., 12 people will be wearing smart glasses: 7 operators, 2 maintenance technicians, 2 quality inspectors, and 1 administrator.

The Figure 11 below shows some of the cost parameters:

Cost Parameters		
initial implementation cost:	$150,000	incl. training and initial content creation and/or integration
recurring training + content creation cost:	$100,000	e.g. to translate more work instructions onto the smart glasses
number of operators with smart glasses:	7	taking into account sales increase & efficiency improvement
number of administrators & support personnel:	5	Consider 1 administrator, 2 quality inspectors and 2 maintenance technicians
cost per smart glass:	$1,750	to be replaced every three years
replacement cost for safety shields & prescription glasses:	$500	per operator per year
annual "SaaS" software subscription?	YES	
investment rate of return:	10.0%	used by the company to make investment decisions

Figure 11: Smart Glasses cost parameters

This leads to yearly and cumulative costs as shown in the figure 12 below:

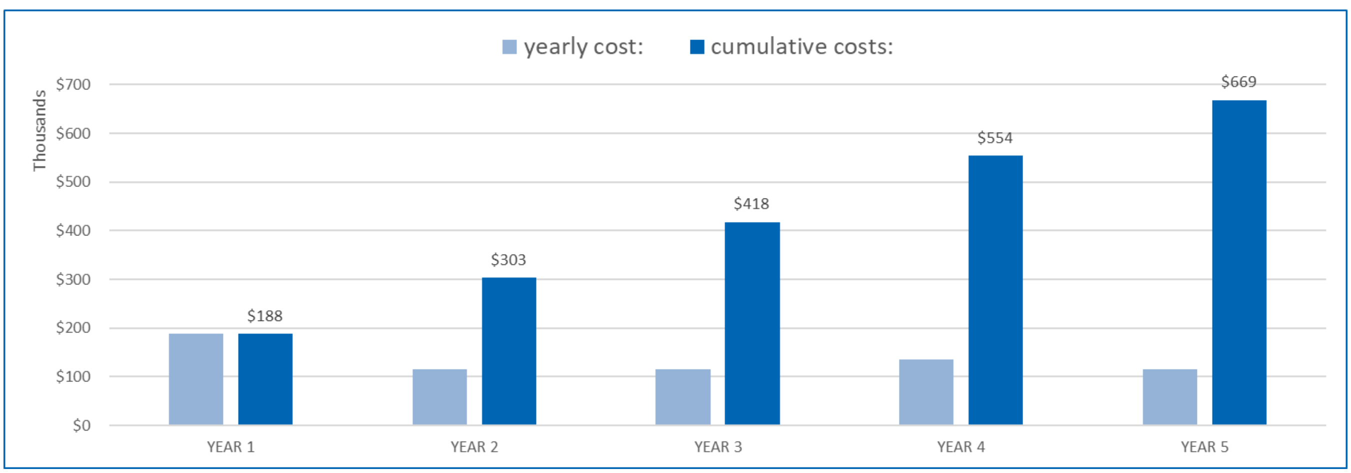

Figure 12: Five-year cumulative cost calculation

Total cumulated benefits

The total benefits possible will depend on the specific company situation as well, of course. If XYZ Inc., by implementing digital work instructions on smart glasses, manages to reduce total downtime losses by 10%, total quality defects by 10%, and average cycle time by 25%, it will achieve a productivity (OEE) increase and therefore an increase in productive capacity of 34.7%. These productivity gains are very significant, but also very realistic and demonstrated at early adopter companies. The productivity gains can either be monetized through labor reduction, or -preferably- by making and selling more products. As shown previously in the figure 8, turning just 10% of the 34.7% total capacity gains into extra sales, thanks e.g. to the shorter production lead times made possible by the extra capacity, will add $358,485 to XYZ Inc.'s bottom line annually. And these benefits accumulate as shown below in the figure 13:

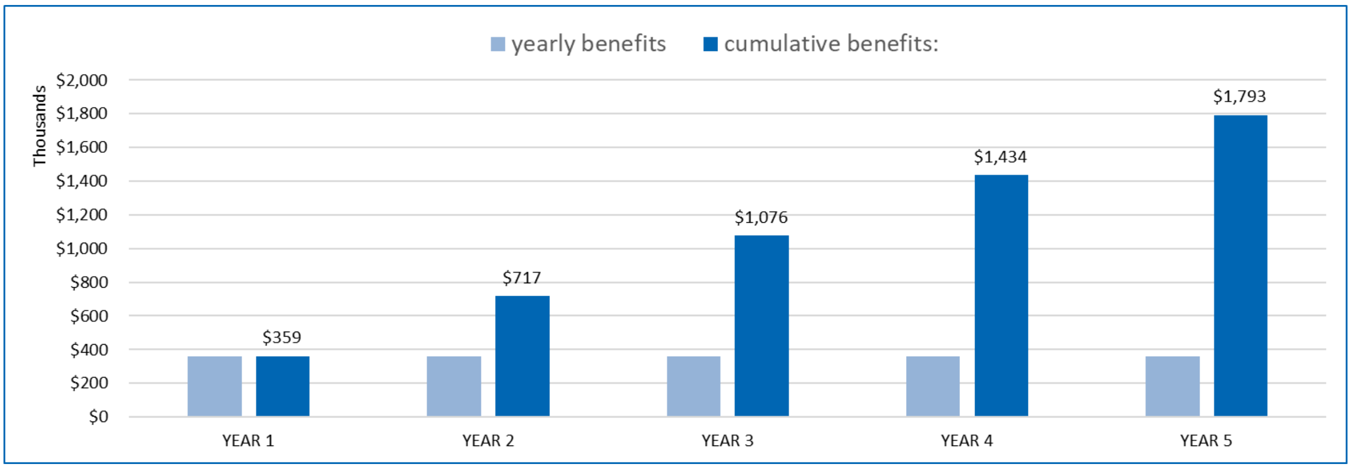

Figure 13: Five-year cumulative benefits calculation

Total cumulated profits

The difference between benefits and costs, is called "Profits", and shown in the figure 14 below:

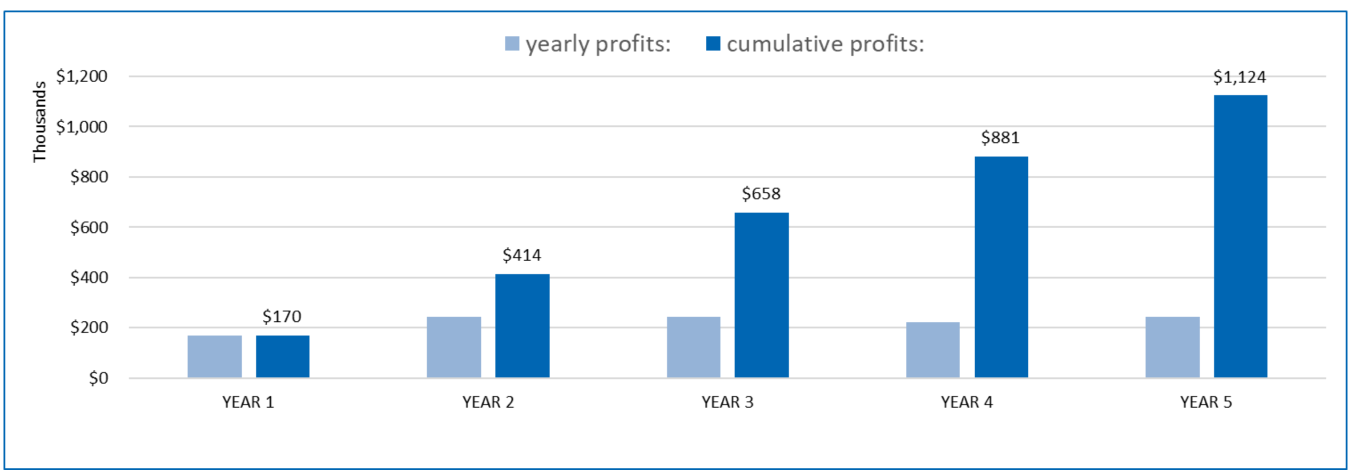

Figure 14: Five-year cumulative profits calculation

Profits = Benefits - Costs

The figure 15 below shows the evolution of benefits, costs, and profits in a single picture:

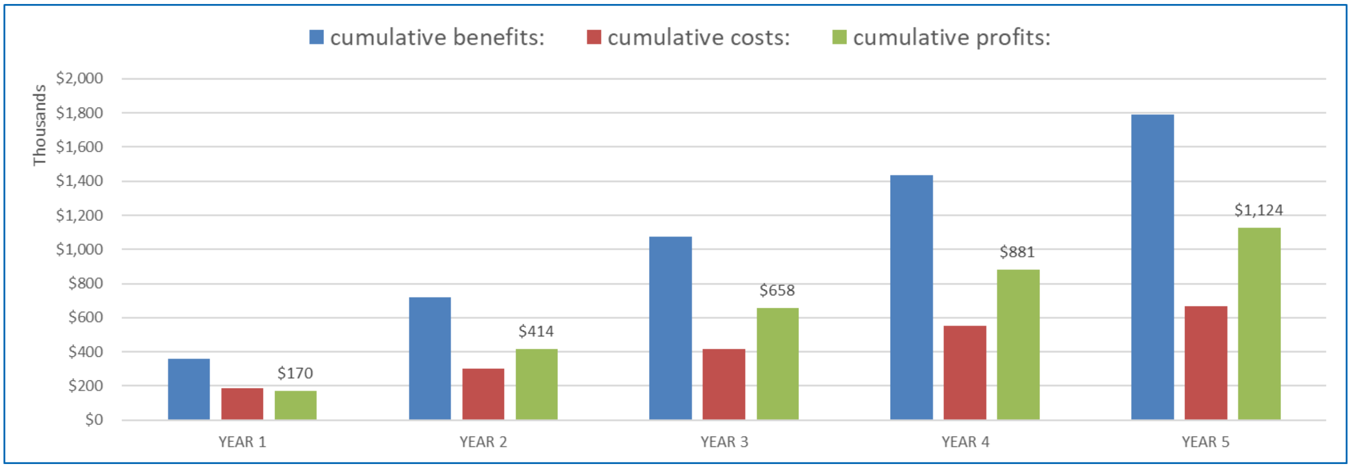

Figure 15: Benefits - Costs = Profits

Net Present Value and Return on Investment

To make an investment decision, what matters is the net present value (NPV) and return on investment (ROI). The NPV and ROI numbers for XYZ Inc. are shown in the figure 16 below:

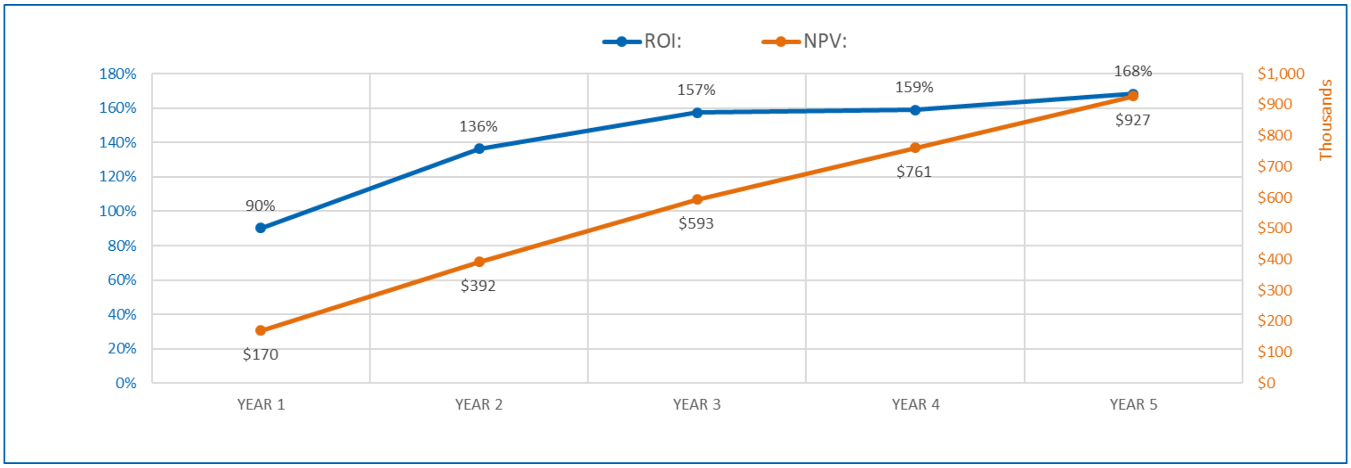

Figure 16: Five-Year NPV and ROI Calculation

With a 10% increase in sales revenue, the ROI for XYZ Inc. after 3 years is 157%, the NPV is $593,263 and the initial payback period is only about 7 months!

Operating Profit and ROI Evolution versus Sales Increase

As discussed in previous paragraphs, being able to increase sales revenue while maintaining or even reducing direct labor cost, manufacturing overhead and SG&A expenses, can lead to very significant bottom line benefits.

In the case of XYZ Inc., a total OEE improvement of 34.7% (as shown in the figure 3) will allow the company to reduce or reallocate direct labor and/or support increased sales volume. Without sales increases, up to 34.7% of the existing direct labor can be reallocated. Alternatively, XYZ Inc. could support sales increases up to 34.7% above current volumes with the existing direct labor. And any scenario in-between.

The figure 17 below shows how annual operating profit increases and 3-year ROI are affected by the amount XYZ Inc. is able to increase sales revenue to capitalize on the increases in productivity:

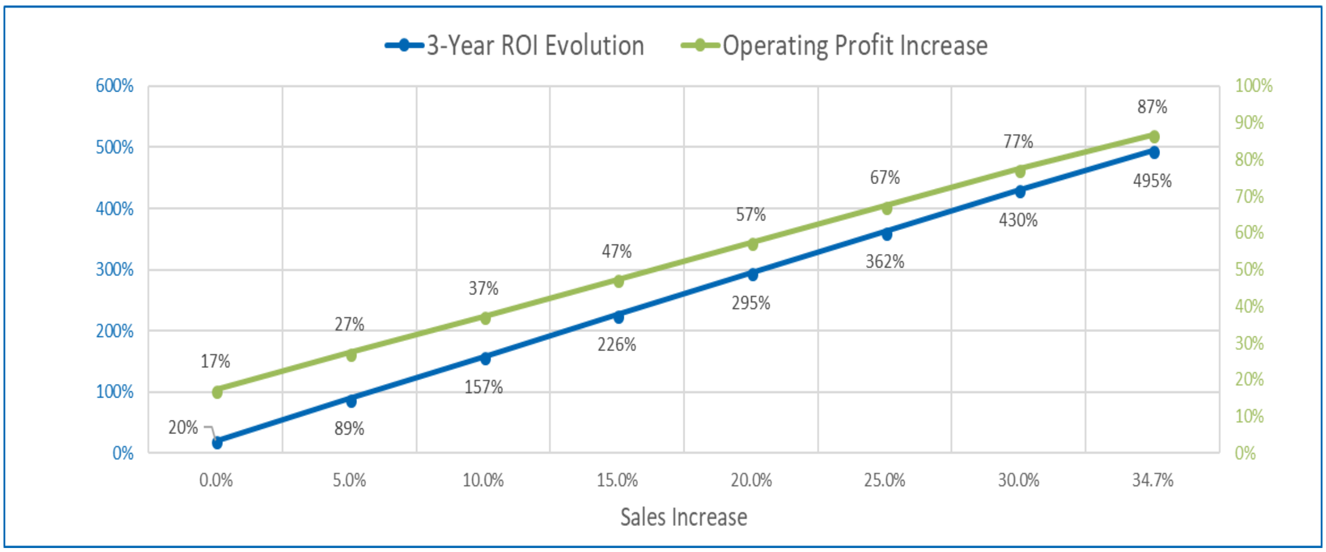

Figure 17: Operating profit and ROI evolution versus sales increase

Thanks to the successful implementation of digital work instructions on smart glasses, XYZ Inc. can achieve 17% in extra operating profit and a 3-year ROI of 20% without increasing any sales yet.

And these numbers go up quickly with increasing sales volumes:

If XYZ Inc. manages to achieve just 5% in extra sales, e.g. by taking advantage of the shorter lead times and increased flexibility made possible by the increases in capacity, its annual operating profit increases with 22% and the 3-year ROI on the smart glasses implementation jumps to 89%.

Best case, when turning close to all -i.e. 34.7%- of the freed-up capacity into extra sales, XYZ Inc. can achieve an 87% boost in annual operating profit, and a 3-year ROI of almost 500%!

Other Benefits

Beyond the obvious benefits of labor cost savings and productivity increases, which are the focus of this white paper, smart glasses also enable other very significant benefits, such as:

- Improved safety through hands-free operation and quick access to safety procedures
- Scrap materials reduction (beyond the lost *capacity* due to scrap)
- Rework cost reduction (offline rework)
- Inspection cost reduction, as smart glasses can help improve the speed and quality of inspection activities
- Maintenance and repair cost reduction, as smart glasses can help improve the speed and quality of maintenance and repair activities
- Setup time reduction, through step-by-step setup guidance
- Faster and more accurate picking/kitting
- Training cost reduction, as smart glasses are a very effective training tool, reducing training time up to 70%, with better performance of the newly trained operators
- Administrative cost reduction, as data can be captured digitally by the operator
- Reduced customer complaints cost, thanks to the reduced number of defects and better-quality inspections
- Reduced customer claims, thanks to improved quality and improved documentation

Most of the above benefits can also be monetized ("dollarized"), for inclusion in the ROI assessment. Other benefits, such as improved employee morale and accelerated continuous improvement, are harder to quantify, but can be very important as well.

Conclusion

It is pretty rare to encounter a new technology that has such incredible impact on people's productivity and companies' bottom line as augmented reality solutions on smart glasses.

This white paper tries to illustrate with a simple example how smart glasses can improve availability, quality, and performance – leading to significantly higher productivity, as reflected by the OEE metric.

Using the productivity gains achieved to reduce labor cost is a logical next step that will typically provide ample return on investment for the smart glasses implementation. But, turning part or all of the extra capacity gained into additional sales volume can work as a true lever to boost operating profits and ROI to much higher levels still.

Before starting a proof-of-concept or pilot implementation project, it is important to clearly define the chosen use case(s), and to estimate any relevant benefits as accurately as possible. Knowing what 1% of better OEE performance and 1% of additional sales are worth in your company's specific situation can provide a good start.

Costs, benefits, and returns will depend on your specific situation. Therefore, it typically makes sense to start with a limited scope, short duration, low-risk and low-cost proof-of-concept project, to prove out the actual value while getting a better grasp of full implementation and scale-up/roll-out cost.

As with any new technologies, it is often beneficial to work with a trusted partner who has expertise and experience in the selection and implementation of the hardware and software solutions that best match your specific environment and use cases, in order to achieve the desired ROI quickly and reliably.

About Gemba Systems Inc.

Gemba Systems Inc. supports manufacturing companies in the digitalization of their operations, especially focused on improving their manufacturing execution systems. We help companies navigate the complex and fast-evolving landscape of "smart manufacturing" and the Industrial Internet of Things. We offer guidance, tools, and hands-on support in the selection and implementation of those industry 4.0 technologies that will best support our clients' most critical business processes, and the people who perform them.

For more information, please see www.gemba.systems or contact us at alain@gemba.systems